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Additional Land at What Price? —Responsible Use of the Tropics in a Food-Population Confrontation

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The tropics does not need more food. It needs a means of evaluating the resources it has and generating social systems that will maximize the standard of living possible with those resources (12). It is not important to maximize the number of people on the earth's surface, but rather to maximize their standard of living. The question then becomes, "will an increase in the amount of tropical land put under cultivation result in a long-term increase in the standard of living of the people associated with that tropical land?" As I travel about the tropics, largely attempting to work in such as yet uncultivated lands, my immediate reaction in each place is that, with respect to material resources, the answer is "no;" and with respect to aesthetic resources, bringing further land under cultivation will actually lower the long-term standard of living of tropical peoples. However, documenting this conceptually, to say nothing of factually, is an extraordinarily difficult task, one that would take a lifetime of work by many people. Here, I can simply touch on a few of the more salient points.

From the very first, I acknowledge that I am dealing with the nastiest of all social dilemmas. I am asked to hold forth on the problem of replacing nature's violence and the inefficiency of ignorance, with the oppression involved in the limitation of human desires by humans other (at least in part) than those doing the desiring. My conscience can survive only in the refuge of a belief that there is no question that people will have their freedom limited, but there is a question of how to bring about that limitation most painlessly [e.g., (3)]. In this limitation, the motivation is a horrible snarl of self-serving moral pontification, genuine concern about the standard of living of future humans, contemporary desire for resources, and educational condescension.

In dealing with the question of putting new land into cultivation, we have perhaps the most potentially explosive of all land-use conflicts. The virgin habitat has the largest number of potential uses it will have in its history. Its value is undefined, and humans often assume more value in the unknown than the known. The greatest variance in opinion as to what it may be used for is therefore possible. Furthermore, since use of land is part of the definition of ownership, its ownership is maximally vague at that time. When one steps from the virgin lowland rainforest, with its thousands of species of animals and plants, into a newly cut squatter's clearing and watches the Costa Rican "landowner's" caretaker put a match to the squatter's house, one feels the conflict most directly. Likewise, after staring for a week at a .30-caliber bullet hole at gut-level through the dashboard of a Landrover purchased from the deceased gamewarden's agency in Uganda, I began to feel very much like this is not an academic subject.

"It is generally accepted that over the next several decades a rising share of the growth of food production in the less-developed countries will come more from increasing yields and less from bringing new land under cultivation" (4). It is evident that bringing new land under cultivation is not high in the priorities or minds of the policy-influencing and decision-making big-time agriculturalists high in the world administrative structure. The 9 May 1975 issue of Science magazine, which examined virtually all the conventional background problems in world food production, devoted *no* article to the question that has been assigned to me by the convenors of this symposium, nor did any individual article spend even a paragraph on the subject. The editor of that esteemed magazine then has the gall to say in his editorial of 8 August 1975, "In many ways, Brazil today is reminiscent of the United States of generations ago. Vast areas of the country are unoccupied. Were the potentials of the country realized, it could probably sustain more people at a higher standard of living than could the United States." My question would seem to be a nonquestion. However, I assure you that it is not a nonquestion to the settlers that have been moved in along the Trans-Amazonian highway or are likely to be moved onto the white sand soils along the Rio Negro. It is a real question to the rangers of Santa Rosa National Park in Costa Rica trying to keep out 200 head of cattle when half the fences are down and the neighbors try to burn the park each dry season. It is a real question to the wild-game hunters of Doula-Edea Fauna Reserve in the Camerouns when they find that they can no longer hunt because someone from a far-away place wants to study monkeys.

From these examples, I think you can see that the global disinterest in cultivating new land is not so much due to some new philosophical awareness, but rather that the less-developed countries are running out of new land to put under cultivation, and if new land is cultivated, its yields are so low that the output makes no international splash anyway.

I have a problem of definition. Virtually all land in the tropics is subject to some kind of food or other resource harvest. Therefore it is false as well as condescending to speak of putting "new land" into agriculture. The Amazonian Indians are (were) harvesting wild game and plant products, some of which they grew, for a very long time before the Trans-Amazonian highway was conceived. The real question is, what are the costs of

putting it into uses that produce products that are available to the world at large, or that produce products for a segment of a country's population that the government of that country views as a political force to be dealt with. Cast in these terms, I can at best talk about the costs of new land development *to someone,* with the realization that to someone else these are not costs, but net benefits, because the costs *to them* are small enough that the benefits far outweigh the costs.

Related to this problem of definition is the question of how one determines if land is "new land." Generally, one says that, if a land is producing very little of use to the outside world, or supporting very few people, then it is unused or new land. There is immense heterogeneity in the abilities of tropical soils and climates to produce materials of use to man. Lush green forests at high elevations on tropical mountains may have virtually no productivity owing to the high rainfall and the low temperatures (e.g., 14); one cow per 100 acres would be overgrazing. Looked at another way, a production rate of 1 calf per 100 acres per year from cleared pasture in this habitat may be a very high production rate, the outcome of very intensive agriculture. Very nutrient-poor white sand soils at low elevations are susceptible to the same problem of definition (15). The forested area between fields in slash-burn agriculture is likewise often thought of as nonproductive. Its value has to be measured as the cost of the fertilizers, tractors, pesticides, and vigilance that would be necessary for the cultivated field were the forest (fallow) not present, and the value of the wild protein that it produces. Finally, if a given piece of land produces just enough to feed a stable and inconspicuous population, it will commonly be thought of as nonproductive or even "new land." By some curious twist of logic the nonresidents have decided that residents should make way for outsiders to expropriate it to quiet their restive slum dwellers.

But now that we have an introduction to the subject, what really can one say about it? Since the costs of putting new land into cultivation are not absolute, but rather situation-dependent, can I say anything that would not be better said by some agroecosystem manager with respect to his or her specific habitat? Since my audience is presumably in large part not made up of such managers, perhaps I can at least identify a few of the costs that such managers would probably take into account.

NATURAL HABITATS AS BIOLOGICAL FILTERS

Substantial tracts of natural habitats are needed as biological filters to maintain gene and recombinant pools as we now see them. Most of a very large number of offspring die in natural habitats before they attain reproductive age. The selective nature of this death insures that genotypes and phenotypes persist in the forms we desire with no expenditure of effort on our part. A zoo, a stored seed bank, or a seed-plantation cannot and does not provide this selection. Selection in these man-controlled habitats is for certain traits deemed of importance at the time, but quite possibly irrelevant to the agroeconomics of humans in the future. Furthermore, a much higher percentage of the juveniles survive to reproductive maturity in a zoo or plantation than in a natural habitat. Of course, some of these juveniles may be highly desired by man, and that is the basis of agricultural breeding. However, what is generally unappreciated is that, for example, every tree that is harvested by a lumberman is a one-in-a-million organism, and it takes the forest to weed out its 999,999 brothers and sisters.

Therefore, I would argue that in destroying all natural habitats, we not only lose species, genes, and recombinants, we lose the environment that molds them to the morphological, behavioral, and physiological phenotypes that we do in fact harvest or otherwise use. May I note in passing that even if heavily sown with seeds, only a tiny fraction of which survive, even the wildest plantation in no way approximates a natural habitat as a biological filter.

Just as one may ask how large a tract of land is needed to conserve a normal tropical animal and plant community without losing species (e.g., 18, 19), one may ask how large an area is needed such that many of the species do not evolve into something quite different, even if they do not go extinct. In short, three square miles of tropical deciduous forest may sustain a breeding population of *Cedrela odorata* (one of the Central American mahoganies), but after 50 generations in this circumstance will it be recognizable as *C. odorata* from a lumberman's viewpoint? The answer to this question is not available from the literature, though it could probably be obtained with many years of research. What *can* be stated with certainty is that the area required to keep the various species alive is going to be much less than that required to keep them as what we now recognize as species.

HOW SCARCE IS DEAD?

How do we know when a habitat has been reduced to the point in size where further conversion of that habitat to human use will result in massive extinctions and irreversible events? As habitats approach nearly total destruction, people begin to census the more conspicuous or valuable species and to wonder how close they are to extinction. This suggests that they have assigned some cost to their extinction, a cost they might not be interested in paying. There is a major difference between plants and animals with respect to such a survey. As lions, ducks, elephants, or tapirs start to get rare, the abundance of adults is a fairly reliable index to how many are left, or at least what is their potential for recuperating if allowed to do so. Furthermore, if left alone, in many cases they will begin to increase in numbers and often do this in a variety of habitats (some of which are definitely not those in which they were abundant in natural circumstances). In short, if allowed to do so, the larger animals move about in search of food and mates, take care of their young, and concentrate in whatever good fragments of habitats happen to remain.

With tropical trees, the story is different. Large areas of the tropics are now converted to brushy or grassy pasture with scattered pasture, fencerow, and roadside trees. These trees were saplings or adults at the time the forest was initially cleared. For example, in the lowlands of Guanacaste Province, Costa Rica, most of the individuals of a good 50% of the large tree species are either already in

this category or almost there. If one chooses the namesake guanacaste (*Enterolobium cyclocarpum*), and looks about, one has the impression that this tree is certainly not an endangered species. Huge adults dot the countryside. Each year the adult tree population produces billions of large viable seeds. The semi-sweet pods are eaten by thousands of cattle and the seeds dispersed much as they once were by deer, peccaries, and rodents. However, this tree is effectively extinct in these pastures. Each year a small number of adults are burned, cut, or die of senescence. They are not being replaced. The guanacaste seeds germinate in pasture soil and then the seedlings are baked to a crisp by the sweeping winds, the burning sun, and the pounding feet of the cattle. The seedling-sapling age class is totally missing except in the few acre patches of forest that effectively act as nurseries. In short, the costs of removing the last scattered fragments of forest is that entire populations of many trees are thus extinct, even though the countryside is dotted with long-lived adults. Not only are the habitats for seedling survival being lost, but also the pollinators and seed dispersal agents. Guanacastecos are going to wake up one day and have not only a treeless plain, but also no opportunity to rapidly replace it with the trees that were once there. My point is that a tree can be an endangered species at a much higher adult density than is the case with a large animal. Trees do not have extensive post-natal brood care, do not migrate to the local remnants of good habitat in times of climatic or hunting crises, and do not move about in search of mates.

RECOVERY OF TEMPERATE AND TROPICAL FORESTS

How does the removal of 90% of a tropical forest habitat reduce later options as opposed to the removal of the same amount of a mid-latitude forest habitat? I am certain that one could reconstruct a pre-Columbian tree species list for the state of Illinois by driving 100 miles of back-country roads and listing the species of trees seen in pastures, woodlots, and fencerows. At worst, one might miss one or two of the most specialized species. Over similar mileages of dirt roads in Costa Rican deciduous forests that have been converted to pastures and fields, one might pick up 75% of the original tree species (but fully 50% of these would be nonreproducing adults remaining from incomplete cutting 10-200 years ago). Moving to a rainforest site, such as the pasture, old banana plantings, and contemporary oil palm plantations in the southern Pacific lowlands of Costa Rica, not over 5% of the original tree species can be recovered from fencerows and woodlot remnants. To put it another way, by the mid-1800's, there was no forest left in the state of West Virginia. Now it is largely forested. In another 300 years, that forest will be very similar to the original one, with the exception of the elm, chestnut, and passenger pigeon. By the late 1960's there was no forest left in El Salvador. In 5,000 years of undisturbed regeneration, Salvadorean forests will not even approximate the original forest ecosystem in species composition (though the overall structure may not be too different).

Why don't tropical forest trees maintain themselves as fencerow and woodlot breeding populations? I have already mentioned one reason. They often require the physical conditions of the forest for successful seedling growth. Additionally, many require specialized pollinators and seed dispersal agents. For example, where the rodents have been eliminated by farming or pasturing in Guanacaste, the woody indehiscent pods of the major lumber tree *Hymenaea courbaril* lie under the parent tree until scolytid beetles kill the seeds, or the seeds germinate inside the pods and the seedlings die because they cannot get out (16). This tree is also bat pollinated, and it will be most interesting to see what happens to its seed set when enough of the bat-visited tree species in the habitat have been removed that the nectarivorous bats disappear. As pesticides eliminate the bee species that pollinate both cotton and wild plants, it will likewise be of interest to see how the seed production of the entire community falls off. (Not that it really matters, since there is no place for seedlings to survive.)

But one is inclined to argue that when we want trees back in Guanacaste, all we have to do is go to Nicaragua or Panama and get seeds and plant them under weedy shade trees and re-create our forest. Problem one: the Nicaraguans and the Panamanians are saying the same thing. Problem two: can we also get and introduce the pollinators and dispersal agents from Nicaragua and Panama? Problem three: the Panamanian and Nicaraguan gentoypes may produce quite different phenotypes in Guanacaste than we want them to. Problem four: during the years without trees in Guanacaste, it is likely that the populations of mycorrhizal fungi have been eliminated or drastically reduced in density. Can these be reintroduced successfully? If they can be, can strains be found in other geographic habitats that will work in Guanacaste (and see 8)?

UNCULTIVATED LAND AS SOURCE AREAS

Are unused habitats or vegetation imporant sources of parasites and predators for biological or integrated pest control in tropical agricultural systems? With the exception of highly controlled colonial agricultural systems, largely on tropical islands, which are effectively run with as close supervision as are mid-latitude systems (e.g., 7, 17), biological control in a deliberate sense is effectively nonexistent in the vast majority of tropical fields and pastures. Therefore, pragmatically, the question cannot be answered in even a general sort of way. Also, no one has ever discovered where the parasites and predators found in a specific tropical field spend their time when hosts are absent. While forest and other natural habitat remnants may harbor important parasites and predators, they may also harbor important pests during the dry season or other times when crop plants are unavailable. Which of these two roles is the more important will vary from site to site and from crop to crop, and can be determined solely with respect to a particular situation. From the biological control viewpoint, we simply cannot say whether the loss of marginal habitats and land to more intensive agriculture will result in a net gain or loss. However, I can state with certainty that their loss prevents us from ever finding out.

In like manner, it is often asked if irrigation in areas with a severe dry season will result in severe pest outbreaks, since the ditchside vegetation is a green oasis for herbivorous insects during the dry season. Here, we might view the dry season as the "new land" and ask if it should be brought under cultivation. It is clear that natural riparian vegetation is an important habitat for tropical herbivorous insects that are passing the dry season as active adults (13). Furthermore, moist sites are also refuges for carnivorus insects. However, it is obvious that not all species behave this way. Whether irrigation will result in changed pest problems depends largely on whether a particular insect species behaves like the average insect species. This can only be determined by careful field trials, and is one more example of how ecological generalities should not be used to prohibit particular agroecosystem experiments (11).

May large tracts of unmanaged land be viewed as important sources of the more migratory insects or vertebrates that are significant as pests or as controlling agents? Under their own steam, this depends entirely on the agroecosystem that is planned for the region. However, unmanaged land could conceivably contain important pools of insects to be used in pest control programs in other areas, provided, of course, that the agriculture in the other areas is sophisticated enough to make use of such a pool (which seems highly doubtful for most of the contemporary tropics).

KEEP SOME PESTS

Insects are a major problem in the organized production of forest trees. As the crop is of low value per year, high cost pesticide solutions are often out of the question; therefore, biological or cultural control systems are particularly attractive. It is often noted that some trees introduced to new continents are relatively free of pests important to the production of a particular product. For example, the native species of *Hypsipyla* shoot borers make the growing of *Cedrela* and *Swietenia* mahogany plantations impossible in the neotropics. Forest entomologists have noted that these neotropical species of *Hypsipyla* also attack the introduced species of Meliáceae, such as *Toona* spp., but die without doing damage (9). The same situation occurs when *Cedrela* is introduced into Australia or Africa. Great optimism has been expressed that, for example, large plantings of *Toona* are in order in the neotropics since this tree is resistant to neotropical *Hypsipyla* (10).

At this point, we may ask what is the cost of lumbering out the last remaining *Cedrela* and *Swietenia* in the woodlots and fencerows in the area of the proposed *Toona* plantations? The cost is that there will be extremely intense selection for *Hypsipyla* strains that can handle the resin and other chemical defenses of *Toona* just as they now handle the chemical defenses of *Cedrela* in the neotropics and *Toona* in Australia. The process is no different than selecting for resistance to parathion by blanket spraying large agricultural areas. On the other hand, were a large number of native Meliaceae to be left in the vicinity of the plantations, they should serve as superior hosts and the moths they produce should have at least the chance of genetically swamping new genotypes with strong resistance to *Toona* defenses. In short, the cost of removing a small number of low-grade trees may be hugh in the context of large plantings of *Toona*. In fact, one may even recommend the planting of large numbers of doomed *Cedrela* or *Swietenia* among the anticipated Costa Rican *Toona* plantations.

This is a specific case of the general argument that the removal of small fragments or remnants of forest may be detrimental to harvestable productivity. However, it is the sort of decision that might well be made by any alert agroecosystem planner familiar with ecological principles on the one hand, and with the natural history of his or her agroecosystem on the other. Furthermore, in some other case, with some other set of animals and plants, the fencerow and woodlot vegetation might well be more detrimental than beneficial.

WEATHER MODIFICATION?

One cannot leave this topic without mentioning the worry of weather modification by massive deforestation. First, it is obvious that certain kinds of irrigation, local clearing, firing patterns, etc. (e.g., 1, 2, 5, 6) can generate local weather modification. Second, if 99% of a tropical deciduous forest has been cleared for pasture and fields, cutting the remaining 1% is not going to alter the local weather. Equally, if 1% of a forest is cut each year, with last year's 1% regenerating to forest, the cutting is not going to alter the weather of the region. The question becomes at what percentage deforestation these differences become great enough to cause change, and whether that change is good or bad. Only local planning and experiments can determine that. In mildly seasonal areas, for example, extreme deforestation may increase the seasonality of the site, thereby reducing pest problems and increasing crop production. On the other hand, deforestation of drainage basins is a marvelous way to silt in a reservoir or hydroelectric project. The desirability of deforestation depends entirely on the use one expects from the region. It was the right thing for Iowa, the wrong thing for West Virginia.

Finally, I should mention briefly the worry often expressed about deforesting the Amazon River basin. If it is done in such a manner that the forest is replaced with grassy pastures, weed- and crop-covered fields, and regenerating natural or pulp trees, the deforestation should have little or no effect on oxygen production, erosion, long-term mineral loss, or degradation of soil structure. If it is done in a way that leaves large areas free of any kind of vegetation, then the same sorts of negative things that happened on Georgia red clay soils or Russian white sand podsols will occur in the tropics.

CONCLUSION

After a few philosophical points by way of introduction, and a few examples of things that could happen if currently unused areas in the tropics were to be put under close management, I have to return to the question, what is the cost of additional land? You know the general answers – loss of species, loss of options, loss of natural models, loss of million-year-old aesthetic patterns; and if you find yourself in charge of a particular agroecosystem, or some fraction of it, you will know the

specific answers, too. If your society values the things mentioned above, then the losses will be great if additional land is put into cultivation. If your society values them little, if it ranks people (votes) above standard of living, then the losses will be small if additional land is put into cultivation. But, as you can see, I operate from a quite self-centered base. I believe that nature belongs to mankind, not to Britain, Nigeria, Costa Rica, or California. I believe that I have as much right to convert a square kilometer of rainforest anywhere in the tropics into a legacy for all of mankind, as a tropical farmer has to convert it into his 3rd through 8th children. But those who control that farmer don't believe that, largely because they want the support of that farmer and the children of that farmer. And that is my answer to the question that your Society put to me.

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